Impact of gonad shielding for AP pelvis on dose and image quality on different female sizes: A phantom study

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Abstract:

Introduction: In clinical practice AP pelvis standard protocols are suitable for average size patients. However, as the average body size has increased over the past decades, radiographers have had to improve their practice in order to ensure that adequate image quality with minimal radiation dose to the patient is achieved. Gonad shielding has been found to be an effective way to reduce the radiation dose to the ovaries. However, the effect of increased body size, or fat thickness, in combination with gonad shielding is unclear.

The goal of the study was to investigate the impact of gonad shielding in a phantom of adult female stature with increasing fat thicknesses on SNR (as a measure for image quality) and dose for AP pelvis examination.

Methods: An adult Alderson female pelvis phantom was imaged with a variety of fat thickness categories as a representation of increasing BMI. 72 images were acquired using both AEC and manual exposure with and without gonad shielding. The radiation dose to the ovaries was measured using a MOSFET system. The relationship between fat thickness, SNR and dose when the AP pelvis was performed with and without shielding was investigated using the Wilcoxon signed rank test. P-values < 0.05 were considered to be statistically significant.

Results: Ovary dose and SNR remained constant despite the use of gonad shielding while introducing fat layers.

Conclusion: The ovary dose did not increase with an increase of fat thickness and the image quality was not altered.

Implications for practice: Based on this phantom study it can be suggested that obese patients can expect the same image quality as average patients while respecting ALARA principle when using adequate protocols.

Introduction

In clinical practice AP pelvis standard protocols are based on optimisation studies for average size patients.1,2 However, as the average body size of the western population has increased over the past decades, radiographers have had to adapt radiographic technique including exposure factors in order to produce optimal images with adequate image quality and minimized radiation dose to the patient.3 Imaging overweight patients requires an increase in exposure factors, which results in scatter radiation that overall decreases image quality.4

The ALARA principle requires that the radiation dose to the patient is kept As Low As Reasonably Achievable, in order to reduce the adverse effects of ionizing radiation. Gonad shielding of females with regards to this principle has been advocated as an effective way to protect the gonads as studies have found that gonad shielding reduces the dose to the ovaries by around 50%.4 However, due to the position of the ovaries and common mistakes in positioning of the gonad shielding, resulting in repetition of the ex- amination, the ALARA principle is more complex than often presumed in female AP pelvis imaging.6 In contrast, male gonads are overall easier to protect with gonad shielding as they are outside the body.6

The use of female gonad shielding for pelvic radiography is subject to much debate in the radiography field. Multiple studies have investigated the effects of gonad shielding on the radiation dose and image quality, however none have considered differences in body thickness at the same time.5 Imaging overweight patients requires high exposure factors as compared to standard protocols in order to acquire optimal radiographic images with adequate image quality.4 However, a recent study has found that a higher kV with an increase of fat thickness is not needed.4

The aim of this study is to investigate the impact of gonad shielding in a phantom of adult female stature with increasing fat thicknesses on SNR (as a measure for image quality) and dose for AP pelvis examination.

Method

Image acquisition

The study was conducted using a Wolverson Arcoma Arco Ceil general radiography system (Arcoma, Annavagen, Sweden) together with one Caesium Iodide (CsI) AeroDR image detector (Konica Minolta Medical Imaging USA INC, Wayne, NJ, USA) and an Adult Alderson-Atom dosimetry verification female phantom (Model 701e706) (Figs. 1 and 2). The X-ray tube Quality Control (QC) has been conducted in accordance with an IPEM document by Christie Hospital, Manchester, United Kingdom.4,7 The results of the quality control fell within manufacturer tolerances.

The supine AP Pelvis positioning protocol was followed with a fixed collimation field centring in the midsagittal plane halfway between the imaginary line connecting the Anterior Superior Iliac Spine (ASIS) and the symphysis pubis.1 The 35 43cm image de- tector was placed inside an anti-scatter grid with a grid ratio of 10:1, the x-ray tube contained a 2.5 mm aluminium inherent filtration. Acquisitions used both the Automatic Exposure Control (AEC) and manual exposure factors 1

Figure 1. DR-system used for the study.

Figure 2. Alderson female phantom.

Body size

The phantom was imaged with a range of fat thicknesses as a representation of increasing BMI. Body size and BMI were cat- egorised representing the thickness of the layer of fat that was used (Table 1). Layers of fat were placed anteriorly on the pelvis of the phantom in order to simulate increasing body size. The categories ranged from the standard body size (size of the phantom with no additional fat) (Fig. 3a) to morbid obese (Fig. 3b).

Female body size	Weight (Kg)	Body Mass Index	Fat layer (cm)
Standard	68	21.46	0
Low overweight	73.2	23.10	1
Overweight	79.5	25.09	2
Obese	89	28.09	4
Severe obese	100	31.56	6
Morbid obese	108	34.09	8

Table 1 Fat thickness categories that were used for this study.

a b

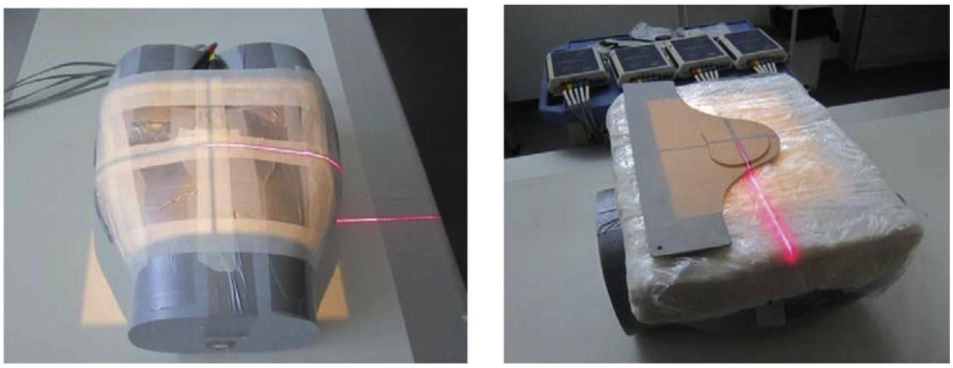

Figure 3. a: category standard female body size without gonad shielding. b: category morbid obese female body size with gonad shielding.

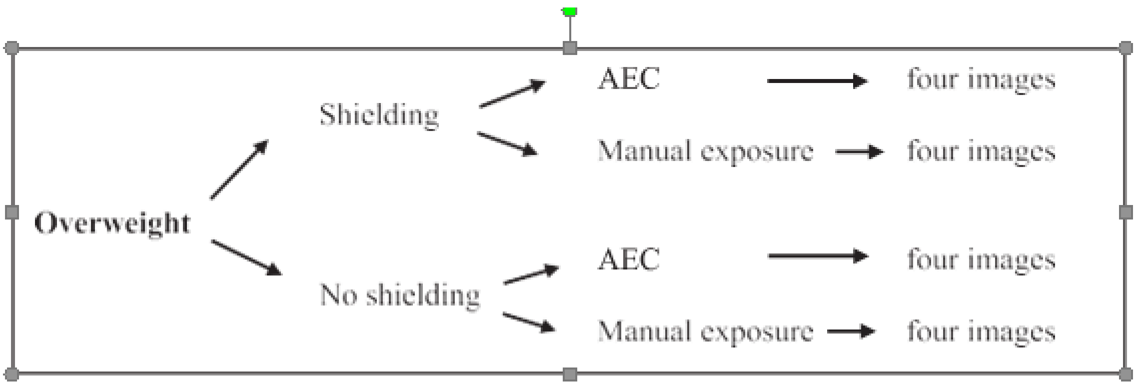

Figure 4. Example Subcategories of each fat thickness category.

A reference image displaying the phantom with no additional fat, was acquired using both outer AEC chambers, with a 100 cm Source to Image Distance (SID) no additional filtration and 80 kVp; this is consistent with the literature.1 A ‘size one gonad shield’ was used (suggested for use in patients of and above 14 years old). Gonad shielding was placed approximately 2.5 cm medial to each palpable

ASIS on the pelvis without obscuring the pelvic bones, with the exception of the sacrum to just below the sacro-iliac joints. The used parameters were obtained from the standard AP Pelvis shielding protocol.1

For each fat thickness category (Table 1), one test image and three standard images were generated using AEC/manual exposure and gonad shielding/no shielding resulting in 4 images per category (Fig. 4), and a total of 72 images.

The test images for each subcategory were used to verify the correct placement of the fat and shielding and were not used for the results. After making all four images of the AEC exposure without use of shielding for each category of fat thickness, the manual exposure for the same category was generated. Then without changing any other conditions, the gonad shield was placed anterior on the pelvis according to the shielding placement pro- tocol.1,5,7 Again both AEC and manual exposures were generated for the same category with the usage of shielding. After all 16 ex- posures (including the test images) were generated of the 'standard category', a layer of 1 cm of fat (low overweight female) was positioned anterior on the phantom. This protocol was repeated for all included fat layers (representing the different body sizes), ulti- mately resulting in a total of 72 images.

Dose measurement

The Dose Area Product (DAP (mGy * cm2)) was measured using a DAP-meter, which was reset after every exposure.

A mobile MOSFET wireless dosimetry system (Model TN-RD-70- W, Best Medical Canada Ltd., Ottawa, Canada) was used to acquire the radiation dose to the ovaries. This system contained a TN-RD-16 reader and five MOSFET (TN-1002RD-H dosimeter) units. The five MOSFET units were placed inside holes in the phantom, covering the area of the ovaries and registering the dosimetry (cGy) in the chosen area. The data was collected by a software program (TN-RD- 75M) that was linked to the MOSFET system through a TN-RD-38 wireless transceiver (Fig. 5).

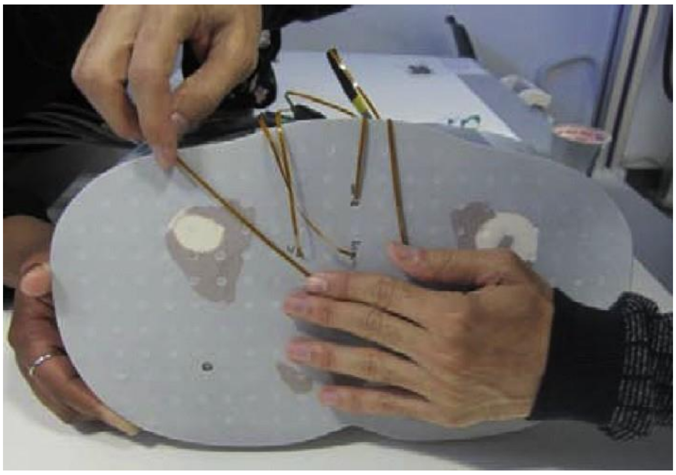

Figure 5. Placement of the MOSFET units inside the Alderson phantom.

Image quality evaluation

The image quality evaluation was performed using physical signal-noise ratio (SNR) measurement using ImageJ software (National Institutes of Health, Bethesda, MD). The SNR was calculated by obtaining the signal and noise from all 72 images. Regions of Interest (ROIs) were either placed manually or automatically, by copying the ROI onto multiple images at the same time. For automatic placement, an ImageJ script was used to place a total of five ROI's in the same region on all of the images. Four ROI's were drawn in homogeneous structures in the pelvis: in the iliac fossa sinister, iliac fossa dexter, ischium sinister and ischium dexter. The fifth ROI was placed in the background (tissue) registering the noise (Fig. 6). The SNR was calculated for every exposure using the following formula: SNR ¼ mean of signal (ROI 1,2,3,4)/noise (ROI 5)

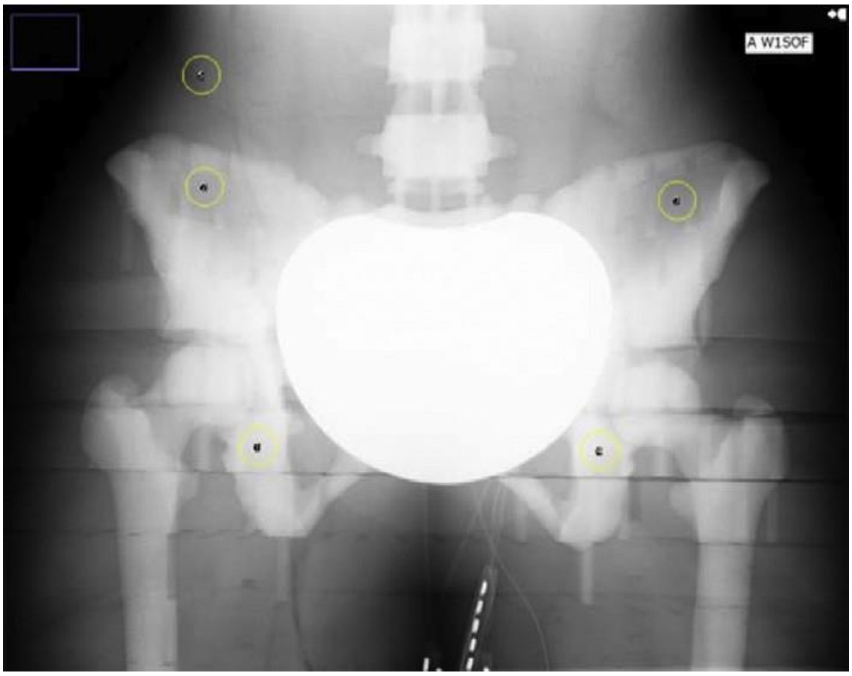

Figure 6. ROI locations on the category ‘obese female with shielding’ in the ImageJ software.

Statistical analysis

After collecting the data for image quality (SNR) and dose (ovary dose and DAP), statistical tests were performed to interpret the data. Both the Statistical Package for Social Science (SPSS) version 22.0 (IBM Inc, Armonk, NY) and Microsoft Excel 2016 MSO (16.0.11901.20070) were used for the analysis. A normality test was performed using SPSS and all data was non-normally distributed. As comparisons between two paired groups had to be made, a Wilcoxon signed rank test was executed to compare the dose following non shielding versus shielding and manual versus AEC for each category of body weight. P-values < 0.05 were considered to be statistically significant. Pearson's correlation was performed to investigate whether there was a correlation between fat thickness and ovary dose and DAP. Pearson's correlation coefficient between 0.10 and 0.29 was considered a weak relationship, between 0.30 and 0.49 a medium relationship and between 0.50 and 1.0 a strong relationship.

Results

Ovary Dose

In Figs. 7 and 8 the effect of technique, shielding and fat thick- ness on ovary dose (mGy) are shown. The ovary dose is lower when shielding is used for both AEC and manual exposures (Fig. 7). When fat thickness increases, the ovary dose is relatively constant with and without use of shielding. The correlation coefficient varied between 0.01 and 0.68 (Fig. 8). Noticeable is that the ovary dose is overall, approximately 50%, lower when shielding is used.

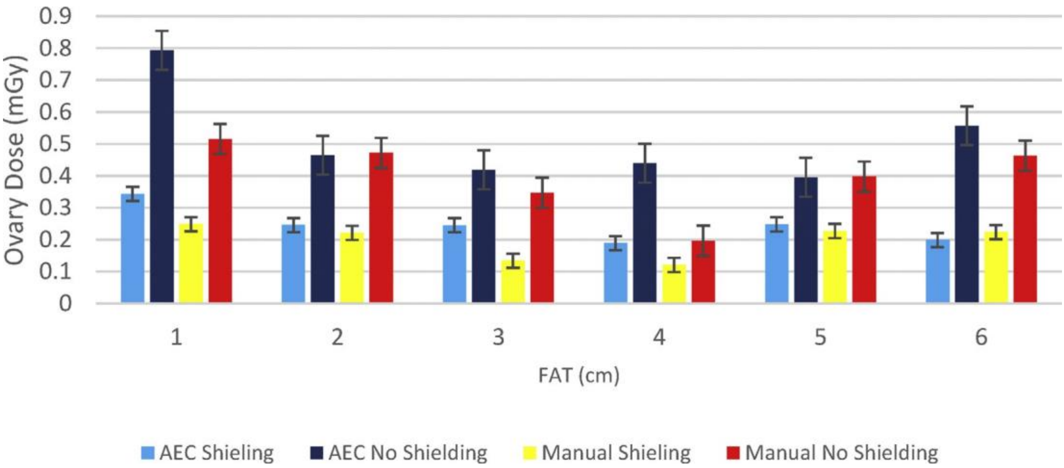

Figure 7. Ovary dose AEC and Manual exposure.

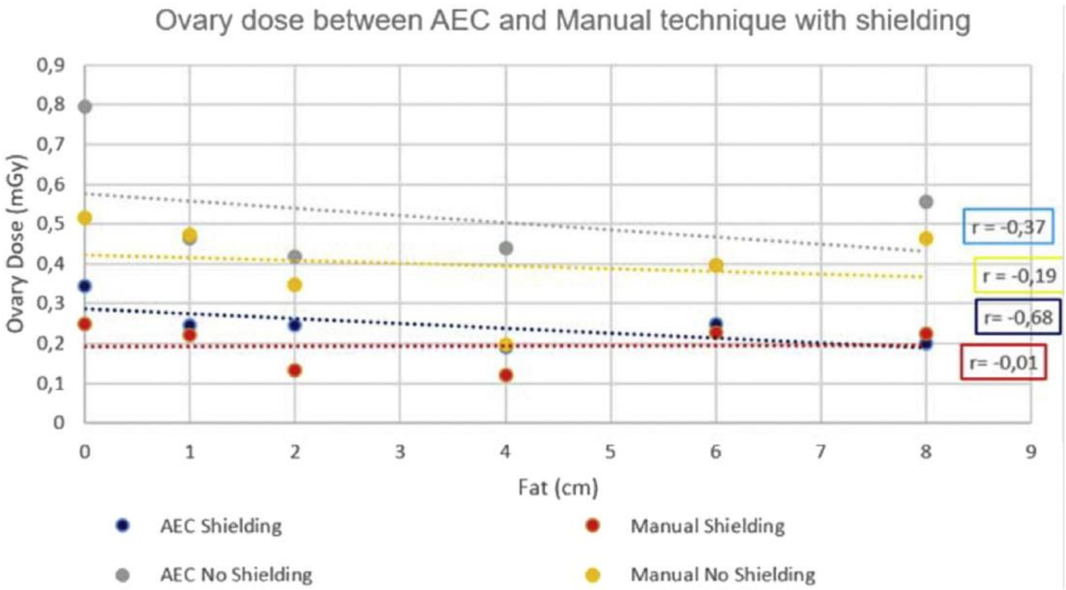

Figure 8. Correlation of fat vs ovary dose e AEC and Manual exposure.

A Wilcoxon test shows a significant difference between the dose observed during acquisitions with and without shielding (P ¼ 0.028). There is no significant difference in dose between fat thickness and the ovary dose with gonad shielding (Table 2).

P-Value	Standard (0 cm)	Low overweight (1 cm)	Overweight (2 cm)	Obese (4 cm)	Severe obese (6 cm)	Morbid Obese (8 cm)
Standard (0 cm)	X	0,386	0386	0,083	0248	0,386
Low overweight (1 cm)	0,386	X	0,386	0083	0,773	0773
Overweight (2 cm)	0,386	0386	X	0,564	0773	0,773
Obese (4 cm)	0,083	0083	0,564	X	0,564	0083
Severe obese (6 cm)	0,248	0773	0,773	0564	X	1
Morbid Obese (8 cm)	0,386	0773	0,773	0083	1	X

Table 2 P-values of comparison between ovary dose and subcategories in fat thickness.

DAP

In Fig. 9 the effects of technique, shielding and fat thickness on DAP (mGy.cm2) are shown. A strong correlation was found be- tween fat thickness and DAP; as the fat thickness increased, the DAP-value increased as well (r= 0.99).

The DAP-value is higher when gonad shielding is used. However, according to the results of the Wilcoxon test, there was no statistically significant effect of technique or shielding on dose (p ¼ 0.28).

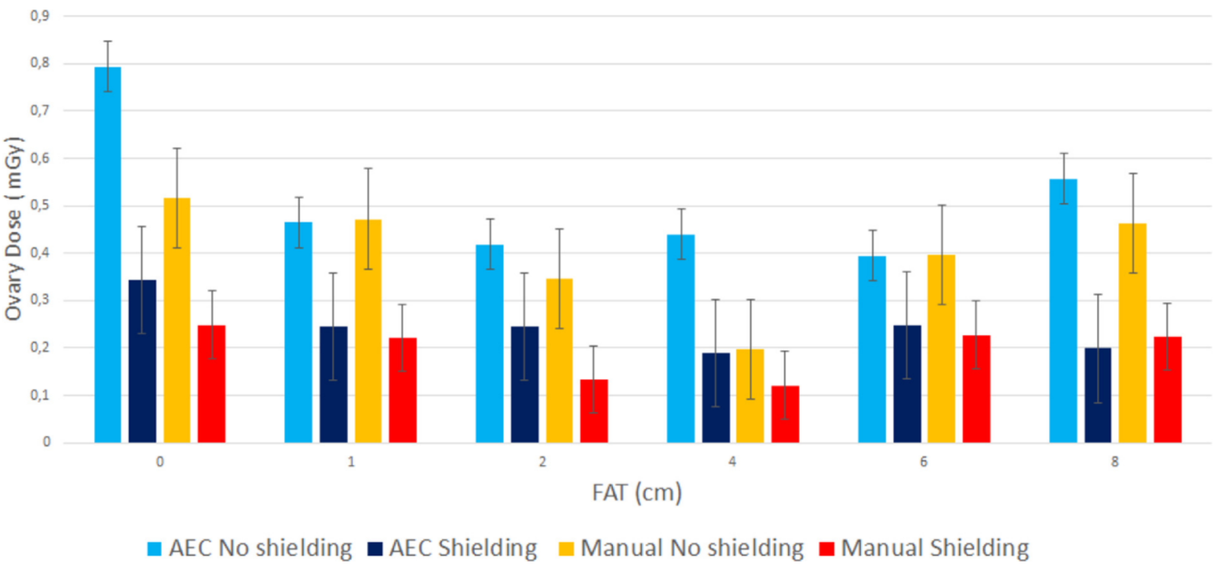

Figure 9. Overy dose with and without shielding-AEC and Manual exposure.

SNR

In Fig. 10 the effect of technique, shielding and fat thickness on SNR (as a measure for image quality) are shown. When fat thickness increased, the SNR remained relatively constant with a correlation coefficient of 0,5. However, it is noticeable that at a fat thickness of 2 cm the SNR increased compared to the other fat thicknesses. There was no difference in SNR by using AEC or manual exposure (Fig. 11).

A Wilcoxon test shows a significant difference, with a P-value of 0.028, between the SNR observed during acquisitions with and without shielding for AEC.

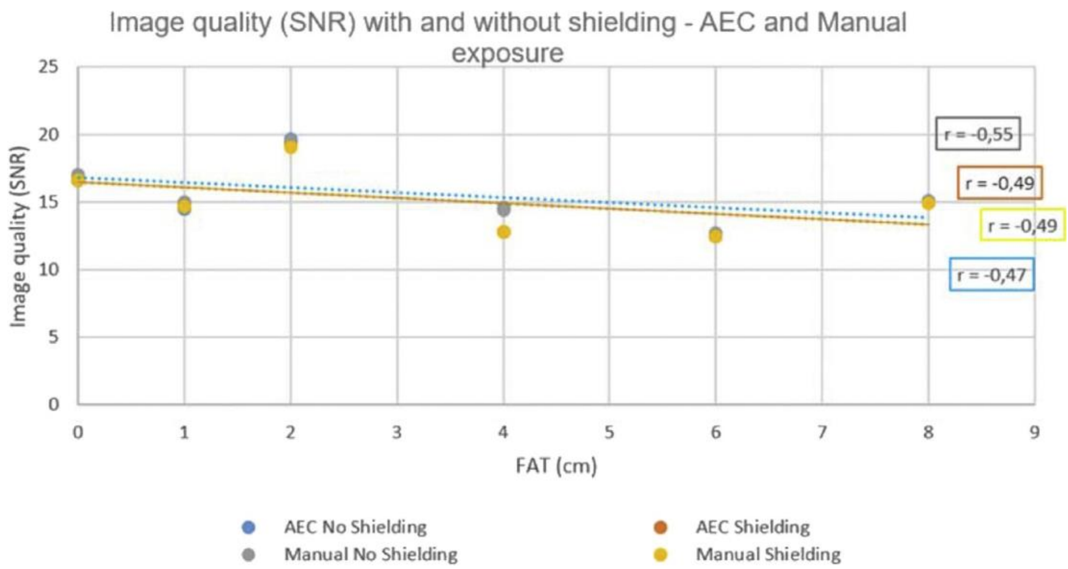

Figure 11. Image quality AEC and Manual exposure.

AEC and manual exposure

The ovary dose is higher when gonad shielding is applied during an automatic exposure compared to the same exposure manually. When no shielding is applied, the usage of AEC results in a lower ovary dose as compared to manual exposure. However, statistically there is no significant difference.

<u>Discussion</u>

The aim of this study is to investigate the impact of gonad shielding in a phantom of adult female stature with increasing fat thicknesses on SNR (as a measure for image quality) and dose for AP pelvis examination.

This study was conducted on a phantom, with different sizes of fat, to simulate different body sizes. Using the different sizes of fat was based on previous research by S. Al-Murshedi. Comparing only the impact of shielding without changing the fat thickness, the ovary dose was significantly lower with shielding with both AEC and manual exposure. Using manual exposure ovary dose was slightly, but non-significantly lower as compared to manual expo- sure. The reduction in dose was almost 50% when using a shield, which is confirmed by other studies.5,6

Regarding the ovarian dose; The difference must be made between the DAP (dose area product), which is the absorbed dose multiplied by the area irradiated (mGy.cm2) and the ovary dose, which is the dose in mGy the ovaries received. The ovary dose was measured very precisely because of use of the MOSFET system instead of using a simulation. Only the pelvis area of the phantom could be used due to restrictions. This might have had an impact on scattering due to the absence of the thorax. The phantom slices had to be held together using tape, this resulted in airgaps which led to artefacts in the images.

The current study showed that DAP increases with increasing fat thickness and even more when shielding is used, but the ovary dose remains generally constant for every patient size. The difference in dose must be absorbed by the adipose tissue before getting to the ovaries, as the overall dose increases with fat thickness.8,9 This differences in DAP- value can be explained by high attenuation of the primary beam by the different fat thickness. In this study the fat was placed only anteriorly which does not simulate the real loca- tion of fat on a female body. Normally fat will be around the body. The protocol for standard pelvis imaging is anterior-posterior (AP). Therefore anterior placement of fat in this experimental setting is admissible. The relation of BMI to fat was not clear during the study as the weight, BMI and layers of fat are calculated via a formula, referenced from a yet to be published article.

Image quality was quantified by the SNR in this current study. The images used for ImageJ were divided into groups as there was a slight difference between the position of the pelvis in some of the images due to adding fat. In every group (standard, low overweight, overweight, obese, severe obese, morbid obese) the ROI's were placed very precisely on the same coordinates. This resulted in the SNR. The SNR remains generally constant when fat increases, but the best SNR ratio was obtained with 2 cm of fat. This might mean that the best image quality is acquired with a patient with a little overweight, in concordance with previous study of K. Alyzoud et al. that showed the impact of fat thickness on AP pelvis radiography.3 Outcomes of this study were that optimal image quality across a range of thicknesses, lower kVp settings were most effective. SNR decreases as body part thickness increased. Outcomes of this cur- rent study could indicate that an increase of fat thickness will not affect the image quality, as expressed in SNR, since SNR remained constant with or without shielding for each fat thickness category. It could mean that using a shield will not decrease the signal-to- noise ratio. The use of AEC or manual exposure had no effect on SNR. For further research it is of interest to investigate image quality in more detail using other parameters such as CNR or using subjective measures in an observer study.

When translated into a clinical setting, this might mean that using a size one gonad shield does significantly reduce the ovary dose, as long as it is placed correctly and does not affect diagnostics or lead to a second exposure.4,10 Moreover, the ovary dose did not increase with an increase of fat thickness and the SNR was not altered. This might indicate that with adequate protocols, obese patients can expect the same image quality as average patients while respecting ALARA principle.

Conclusion

In conclusion, our study shows that shielding is useful to reduce ovary dose for AEC and manual exposures. A strong correlation is found between fat thickness and DAP. When fat thickness increased, DAP-values increased as well. However, the ovary dose and the SNR remain constant with and without shielding, therefore in practice this might mean that as patient thickness increases, a good quality image can be produced without a significant increase in exposure factors. The ovary dose did not increase with an in- crease of fat thickness and the image quality was not altered. Based on this phantom study can be suggested that obese patients can expect the same image quality as average patients while respecting ALARA principle when using adequate protocols.

Suggestions for future studies

Further research on placement of the shielding could be considered, as it does significantly reduce the ovary dose. Also the effect of fat thickness and SNR could be interesting, with the question "what is an ideal patient size for the highest SNR?" Focus on CNR versus image quality could also be a direction.

Conflict of interest statement

None.

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